ABSTRACT

Objectives:
1) To measure stapes height, footplate width (diameter perpendicular to the plane of the crura), and footplate width (diameter in the plane of the crura) and to correlate these metrics between right and left sides.
2) To correlate stapes measurements with mastoid size, an indicator of childhood otitis media.

Methods:
From a group of 41 clinically ear-normal cadavers, tissue blocks from the five crania with the largest mastoid pneumatization and the five with smallest mastoid pneumatization had microCT imaging. Using the ImageJ software package, a 3D model of each stapes was created to determine stapes height and footplate dimensions. Of 60 measurements sought, 52 were accomplished.

Results:
The mean stapes height was 3.31 mm (range 3.16 – 3.51). The mean stapes footplate width was 2.68 mm (range 2.50 – 2.86). Bilateral symmetry was appreciated.

Conclusion:
A wide range of stapes dimensions is confirmed by these specimens. Bilateral symmetry suggests that (non-local) genetic influences may play a role in development. No correlation was found between stapes dimensions and mastoid size (indicator of otitis media) suggesting that this local environmental aspect may not be related to its development.

INTRODUCTION

The stapes has intrigued researchers for greater than 100 years. During the embryological development, the stapes is formed in two parts: the superstructure (capitulum and crura) is formed from the second branchial arch and the footplate formed from the otic capsule. Previous research by Dass et al. (1968) demonstrated marked variation in the stapes structure.

The analysis slowly evolved from “direct” measurements with plain light microscopy to more advanced techniques with the creation of new imaging modalities. Micro-CT imaging systems create high-resolution images with pixel sizes in the micrometer range. This allows for high-resolution 3-dimensional (3-D) models to be generated and analyzed.

Sims et al. (2013) recently evaluated the stapes with micro-CT imaging. This study was limited by not evaluating symmetry in stapes pairs or correlating the stapes metrics with mastoid pneumatization, an indicator for childhood otologic infection. Our study aims to evaluate these unreported stapes metrics while in situ rather than stapes that survived harvesting.

METHODS & MATERIALS

Forty-one adult skulls (82 temporal bones) were evaluated for mastoid pneumatization. Law lateral radiographs were quantitatively assessed by planimetry. Five crania with the smallest mastoids and five with the largest mastoids underwent micro-CT imaging.

20 temporal bones were imaged using Siemens Inveon micro-computed tomography device with a pixel size of 20x20 microns, slice thickness 21.5 microns, and resolution of 46,489 pixels per mm. Specimens were physically reduced to fit the scanner’s imaging aperture.

Segmentation and 3-D volume reconstruction were performed using ImageJ/BoneJ.
1. Stapes was cropped from the surrounding structures and ambient air by hand.
2. “Background” noise was subtracted.
3. Image stack was processed using the leucosurface algorithm of BoneJ which generates the surface model for dimensional analysis.
4. 3D Viewer was used to visualize the STL models. Reference points were marked directly on the 3D models and recorded as X/Y/Z coordinates.

Stapes height was calculated by measuring the distance between a point in the center of the top of the capitulum and a point in the center of the stapes footplate on the medial (vestibular) surface.

Footplate width was calculated by measuring the distance between points on both ends of the long axis of the footplate annulus.

No data for two stapes were available: specimens 11R and 16R did not have stapes at the time of imaging. For two other stapes (specimens 4R and 23L), the crura were damaged prior to imaging, making calculation of stapes height impossible.

RESULTS

| Stapes Height | Overall mean stapes height was 3.31 mm (range 3.16 – 3.51). Right-sided mean stapes height was 3.26 mm (range 3.19 – 3.43). Left-sided mean stapes height was 3.35 mm (range 3.16 – 3.51). In the subjects with both sides, relative bilateral symmetry is appreciated. |
| Stapes Footplate Height | The overall mean stapes footplate height was 2.68 mm (range 2.50 – 2.86). The right-sided mean stapes footplate height was 2.70 mm (range 2.50 – 2.87). The left-sided mean stapes footplate height was 2.66 mm (range 2.50 – 2.87). In the subjects with both sides, relative bilateral symmetry is once again appreciated. |
| Stapes Footplate Width | The overall mean stapes footplate width was 1.23 mm (range 1.06 – 1.46). The right-sided mean stapes footplate width was 1.27 mm (range 1.14 – 1.46). The left-sided mean stapes footplate width was 1.21 mm (range 1.06 – 1.34). In the subjects with both sides, relative bilateral symmetry is once again appreciated. |

CONCLUSIONS

The dimensional measurements were in accordance with previous studies. Using the paired specimens, bilateral symmetry was appreciated for all measures. No correlation was appreciated between the stapes parameters and mastoid pneumatization.

REFERENCES


